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A Modified Anchor Free Localization Technique for Wireless Sensor Network

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Abstract

INTRODUCTION: A novel anchor-free localization technique for a single-hop wireless sensor network is proposed, which is based on internode distances only. The average of the internode distances is mainly used to localize the reference node in the proposed algorithm. Average localization error is used as the main performance metric. The simulation result shows that the proposed algorithm significantly reduces localization error as compared with conventional localization techniques with respect to node density variation and network size.
OBJECTIVES: To find the location of the randomly deployed sensor nodes.
METHODS: An anchor free localization method is used to find the location of the deployed sensor nodes.
RESULTS: Location error is comparatively less in the proposed strategy.
CONCLUSION: For single-hop wireless sensor networks using inters node distance, a novel anchor free localization technique is presented

Keywords: Wireless Sensor Network, Node Localization, Energy Consumption, Triangulation, Optimization.

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1. Introduction

Wireless Sensor Networks (WSNs) are autonomous networks for which there is no need of any pre-established network. It consists of small sensors, control units, transceivers, and batteries. These sensors are deployed over the areas of inaccessibility [1]–[3]. In this type of network, nodes are responsible mainly for routing data to the base station.

In order to compute the physical location of the deployed wireless sensor nodes, localization strategies are used. Finding the exact location of the data is one of the prime concerns in WSN. Erroneous location of the nodes results in enormous data, energy consumption, and degree on connectivity. The localization method of the sensor network is classified into two categories- (1) Range-based localization, and (2) Range free localization algorithms. In the range-based technique, geometrical computation is used. While in range free localization, average hop count between anchor and sensor node is the prime parameter for localization. The accuracy of localization can be improved by increasing the number of nodes in the region. However, anchor nodes are more costly than the ordinary nodes. In range based strategy for getting the higher accuracy additional hardware accessories are required. However, these accessories increase the cost of the hardware such as Received signal strength indicator (RSSI), Time of Arrival (ToA) Angle of Arrival (AoA) Comparison between Range based and Range Free localization Techniques are summarized in table 1,[4], [5].

In this paper, a range free node localization algorithm is proposed for single hope WSN. The proposed algorithm is based on the average internode distance.

There, RSSI value is used to determine the distance between the nodes.

Table 1 Summary of localization techniques

S. No.	**Parameter**	**Range Based Technique**	**Range Free Technique**
1.	Additional Hardware	Required	Not Required
2.	Level of Accuracy	High (85% -90%)	Low (70%-75%)
3.	Power Consumption	High	Low
4.	Deployment	Hard/Complex	Easy
5.	Robustness	High	Low

The rest of the paper is organized as follows, Section 2 presents previous works that have done in the field of localization in WSN. Section 3 is described as the metrics, which are used in the proposed algorithm. Section 4 depicts the proposed algorithms with flow chart. Section 5 presents simulation and performance evaluation of the proposed algorithm and Section 6 concluded the proposed work.

2. Literature Review

Many researchers propose various techniques of localization of WSN nodes. In this section, we present previous research work in the field of sensor node localization.

(Pandey and Varma, 2016)	[6]	In order to evaluate the impact of localization, a distributed cooperative approach based on hybrid extendable range have been proposed.
(Tuba, Tuba and Simian, 2016)	[7]	Localization approach based on bat algorithm is proposed. In the proposed strategy, position of the end nodes in the regions is calculated. After that, using range based strategy positions of the other nodes are calculated.
(Thimmaiah and Mahadevan, 2017)	[8]	An Adaptive Information Estimation Strategy Time of Arrival (AIES-TOA) is presented. AIES-TOA is compared with localization distance error, error tolerance, and Root Mean Square Standard (RMS- STD) strategies.
(Feng, Bi and Jiang, 2012)	[9]	A Dixon approach based on the Received Signal Strength Indicator (RSSI) Algorithm.
(Sharma and Kumar, 2018)	[10]	A 3D-GAIDV range-free localization approach based on correction factor has been proposed to change the average hop size of beacon nodes.
(Prashar, Jyoti and Kumar, 2016)	[11]	Comparison of different range free strategies is presented.
(Najeh, Sassi and Liouane, 2018)	[12]	A genetic and traditional DV hop strategy for range free localization is proposed.
(Shahra, Sheltami and Shakshuki, 2016)	[13]	Evaluation of Fingerprint and Centroid algorithms using Tmote sky based on localization accuracy and average error hav proposed.
(Li, 1969)	[14]	Location error is improved by using modified Distance Vector Hop (DV-Hop) strategy. Main advantage of the proposed DV-Hop is only one node allow to broadcaste message in order to save energy.
(Feick et al., 2015)	[15]	A genetic algorithm for localization is proposed.
(Lin et al., 2016)	[16]	A particle based algorithm based on fixed rules is presented.
(Cai et al., 2014)	[17]	A diagram Based Localization (VBLS), named as weighted Voronoi diagram-based localization method is presented to find the location of nodes based on RSS estimates. However, this technique lacks in calculating accurate distance estimates and leads to improper selection of input parameters
(Kumar et al., 2013)	[18]	A Hybrid Particle Swarm Optimization and Biogeography based optimization for rangebased models presented.
(Jain et. al. 2019)	[19]	A protocol based on Neuro Fuzzy Inference System (ANFIS) Based for Cooperative Wireless Sensor Network is presented
(Shah et. al 2020)	[20]	Weight based approach is proposed for optimum location of nodes.

3. Metrics of Proposed Algorithm

Following parameters are used in the proposed algorithm-

(1) **Received Signal Strength Indicator (RSSI):-** The Received Signal Strength Indication (RSSI) defines the relationship between wirelessly transmitted signal power (P_t), received signal power (P_r), and the distance between the nodes (d). This relationship is expressed as Eq. 1, in which n is the

transmission factor whose value depends on the propagation environment.

$$Pr = Pt \times (\frac{1}{d})^n \qquad (1)$$

(2) **The average distance of a node (D_{avg}):-** If n number of sensor nodes are randomly deployed at (x_1,y_1), (x_2,y_2), (x_3,y_3) ….. (x_n,y_n) with inter-node distance as di,j , $\forall(i,j) \in n$, $i \neq j$ respectively. Therefore, d_{ij} can be defined as –

$$d_{ij} = \sqrt{(x_i - x_i)^2 + (y_i - y_j)^2} \qquad (2)$$

(3) The centroid of the nodes can be calculated as [21] -

$$c^x_{i,j} = \frac{\sum_{i=1}^{n-1}\sum_{j=1}^{n-1} x_j}{n}, and \qquad (3)$$

$$c^y_{i,j} = \frac{\sum_{i=1}^{n-1}\sum_{j=1}^{n-1} y_j}{n}, \forall(i,j) \in n, i \neq j$$

(4) **The average node distance (D_{avg})** between all distributed nodes will be roughly equal to the distance from that node to the centroid (Dc). This D_{avg} for i^{th} node is defined as

$$D_{avg} = \frac{\sum_{j=1}^{n-1} d_{ij}}{n-1} \quad \text{for } \forall(i,j) \in n, \quad j \neq i \qquad (4)$$

(5) Normalized D_{avg}' can be obtained by dividing maximum D_{avg} among all nodes to Davg to particular node $D_{avg'}$ is given By

$$D_{avg}' = \frac{D_{avg}}{(D_{avg})_{max}} \qquad (5)$$

In proposed anchor free localization this D_{avg} and internodes distance are used to localize reference nodes first then for other nodes.

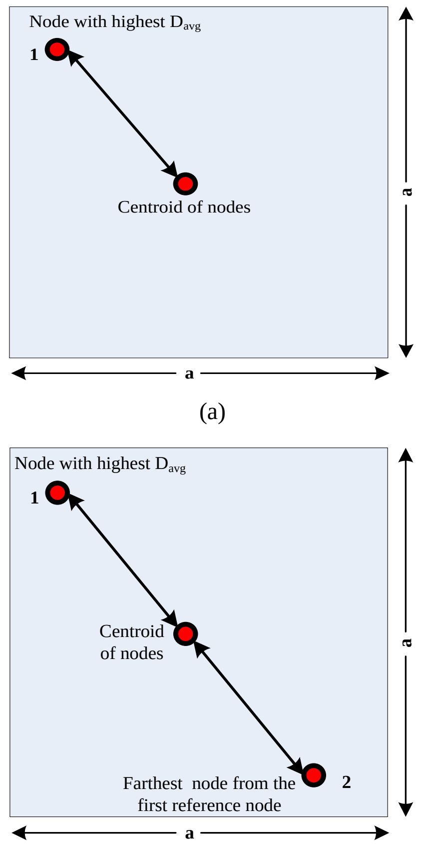
4. Proposed Algorithm

In the proposed algorithm we consider a square topology in which *n* sensor nodes are randomly distributed.

Step 1: Using allocated TDMA scheduling, each node transmits a beacon message with its node ID. The node uses RSSI to measure (n-1) distances (d_{ij}) from all other nodes using equation (1).

Step 2: Compute centroid and average distance using Eq. 3 and Eq. 4, respectively.

Step 3: Sharing of D_{avg} among all the nodes and make the highest D_{avg} node as the first reference node shown in Fig. 1(a).



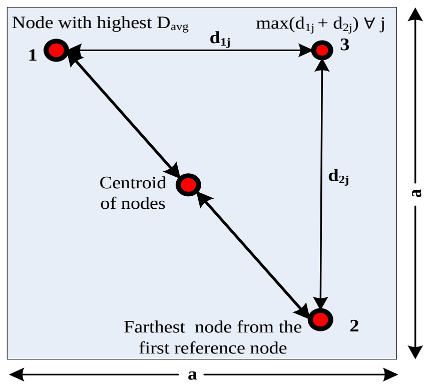
(a)

Fig. 1 First and Second reference node (b)

Step 4: Next reference node is the farthest node from the first reference node shown in Fig. 1(b).

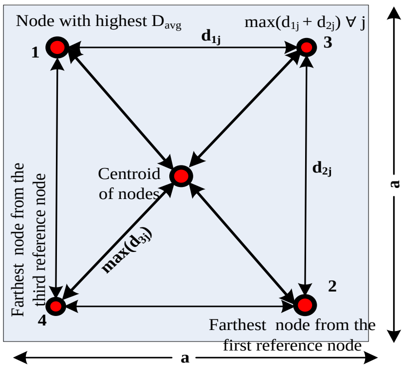
Step 5: Similarly, compute the Third and Fourth farthest node from the previous nodes as shown in Fig. 2

Step 6: Identify the Fifth node which has minimum D_{avg} and make it as origin as shown in Fig. 3.



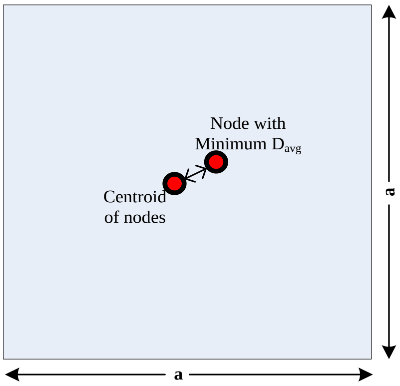
(a)

Fig. 2 Estimation of Third and fourth reference node

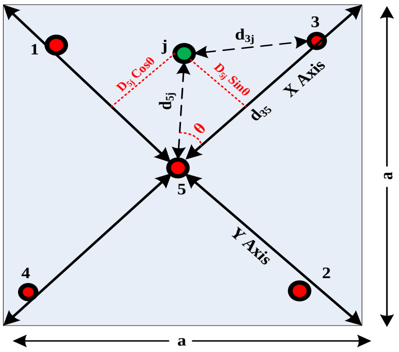


(b)

Fig. 2 Estimation of Third and fourth reference node



(a)



(b)

Fig. 3 Estimation of Fifth reference node and Localization of Node 'j'

By considering reference node 5 as origin and node 1 is considered on the positive x-axis, as shown in Fig. 3. For localization of any node j, compute the angle 'θ' as given in Eq. 6.

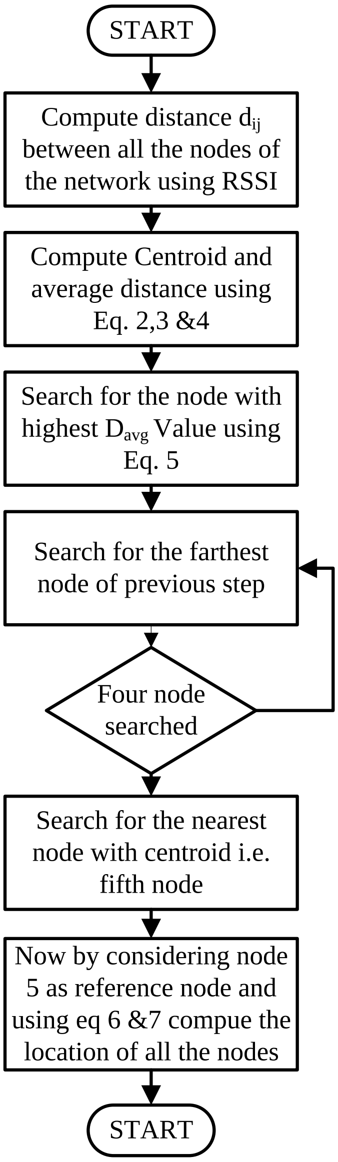
$$\text{Cos}\,(\theta) = \frac{d_{53}^2 + d_{5j}^2 - d_{3j}^2}{2d_{53} \cdot d_{5j}} \tag{6}$$

The localization of node depends on the quadrant in which node is lying, For example, if the node j is lying in 1st quadrant

By using Eq. 6 the x and y position of the 'j' node can be given as:

$$x = d_{5j} . Cos\,(\theta) \;\; \text{and} \;\; y = d_{5j} . Sin(\theta) \tag{7}$$

Flow Chart of proposed scheme



5. Simulation and Performance analysis

For analysis of the proposed algorithm, MATLAB software is used, in which a square field of length 100 m^2 to 400 m^2 with a step of 100 meters, and the number of nodes varied from 100 to 500 with a step size of 50 nodes are considered. For simulation following parameters are used-

Network parameters	Values
Size of Network topology	100 to 400 m^2
Sensor nodes deployed	100 to 500
BS Position	50×50
Eo Node Initial Energy of	0.5J
ϵ_{fs} (free space signal)	10pJ/bit/m^2
ϵ_{mp} (Multi-path fading coefficient)	0.0013pJ/bit/m^4
E_{elec} (Energy in electronic circuitry.)	50nJ/bit
E_{DA} (Energy in data aggregation at CH.)	5nJ/bit
d_{th} Threshold Distance	83m

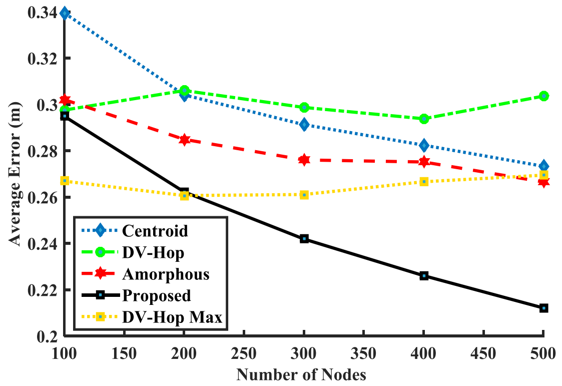


Fig. 4 Average localization Error Vs number of nodes with topology size (250×250) m^2

From above Fig 4, it is obvious that the average localization error decreases with an increase in node density due to the decreased (D_{avg}) which is used in the estimation of reference node localization. Initially proposed algorithm also shows a higher average error, but with increased node density in the topology algorithm shows less average error.

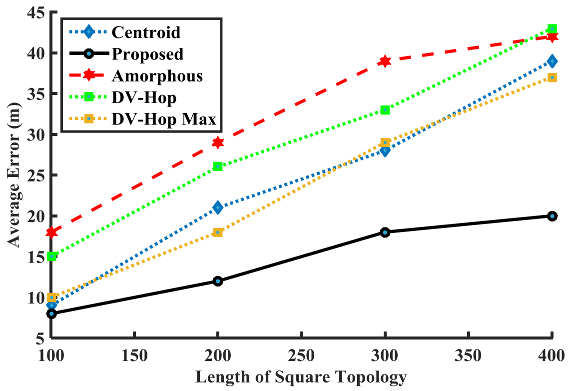


Fig. 5. Average localization Error vs Network size at 200 number of node

Localization error for different sizes of the network would be different as shown in Fig. 5, Initially, in a comparatively small network, comparatively node density is high therefore less localization error occurs. On the other hand, with the same node density will be topology with increased size, high localization error exists, as all positioning estimation depends at D_{avg}, Which uses node density.

6. Conclusion

In this paper, a novel anchor free localization technique for single-hop wireless sensor networks using inter node distance is presented. The proposed algorithm is investigated on the metric of node density and varying network size. Results have shown that the proposed strategy performs better than the existing classical localization techniques such as Centroid, Amorphous, DV-Hop, and DV-Hope Max.

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